Forecast of hydrocarbons non-folded traps in Upper Visean deposits of Dnipro-Donets depression

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Favorable geological preconditions for accumulation of accumulative sand bodies–reservoirs were studied and conditions of formation of related to them lithological, stratigraphic and combined oil and gas traps on the slopes of large near-axial troughs. Features of the geological structure of Upper Visean deposits on the northern slope of Ordaniv trough were investigated. A complex methodology of detecting non-anticlinal hydrocarbon traps, which includes paleotectonic, paleogeographic methods, detailed correlation of natural reservoirs by logging data and 3D seismic prospecting, as well as attributive analysis of the wavefield . The case of peripheral part of the West Solohivske gas-condensate field (GCF) shows the effectiveness of the new complex methodology. The hydrocarbon potential of Upper Visean terrigenous deposits was assessed for the area of Ordaniv trough northern slope in the area of West Solohivske structure.

Key words: forecast, reservoir, hydrocarbons, non-anticlinal traps, depression, Dnipro-Donets depression, Visean deposits

Despite the fact that all the known anticlinal structures have been already known, it is possible to find at their periphery new non-folded traps of hydrocarbons (HC). As estimated, these traps contain over 75% residual resources of hydrocarbons of Dnipro-Donets depression (DDD) [1]. So, the forecast and discovery of these traps is very important for increase of the resource base of the gas industry of Ukraine.

For this purpose we developed the complex methodology based on paleotectonic, paleogeographical methods, lithofacies analysis, detailed correlation of its sand tylosis reservoirs according to data of borehole geophysics (BGP) and high precision 3D seismic survey.

A new method was successfully tested in the West Solohivske Structure which had been well surveyed by drilling and had the detailed 3D seismic survey. The structure is located in the DDD axial zone and associated with the Solokha-Dykan anticlinal trap. In oil and gas relation the West Solohivske Structure belongs to Glynsk-Rozbyshiv oil and gas area.

The Upper Visean stage terrigenous deposits are regionally oil and gas bearing in the DDD axial zone [2].

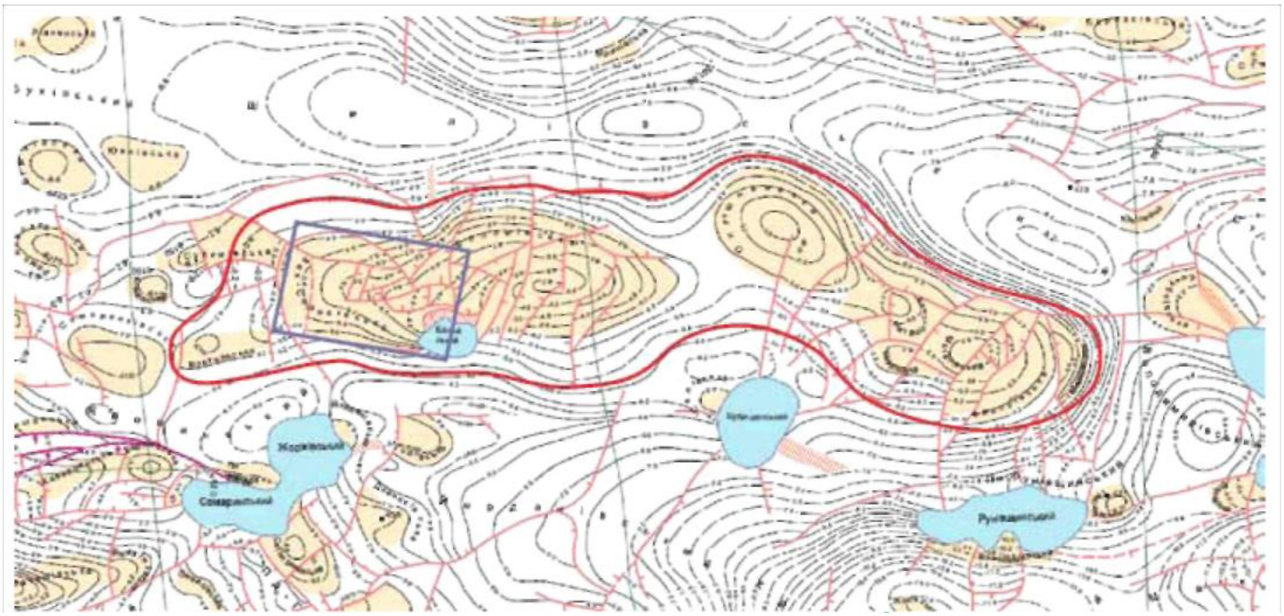

Fig.1. Overview map (fragment of DDD structural tectonic map, C_1v_2)

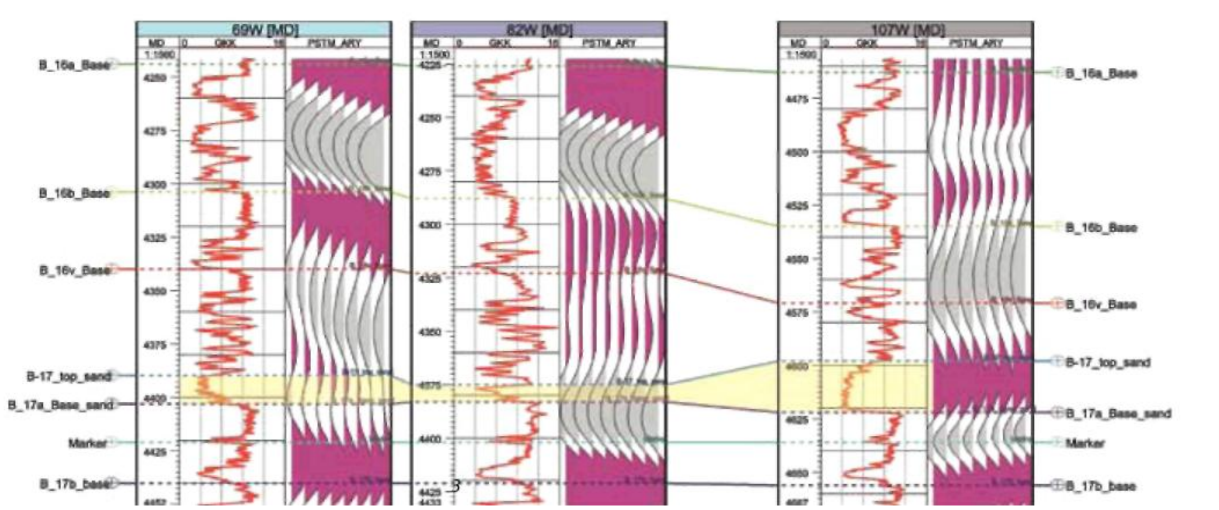

Fig. 2. Paleotectonic reconstruction of Upper Visean Deposits along the line of wells 69-82-107

The industrial deposits of Upper Visean formations from B-14 through B-18 are found in the structures of Solokha-Dykan trap. The majority of deposits are associated with folded lithologically limited traps, a part of which has tectonic and stratigraphical shielding, i.e. the lithographical factor of these deposits plays the key role in formation of oil and gas deposits [3].

In the West Solohivske deposit of the Upper Visean Productive Complex (XII microfaunal bed) there are combined, lithographic and tectonic shielding gas-condensate field (GCF) associated with terrigenous deposits of coastal-maritime genesis. The productive beds are formed by sand layers of the depth from 1 m to 24-30 m, the effective porosity is 7-14% according to laboratory surveys.

The favorable conditions for formation of sand accumulative bodies with which the non-folded Upper Visean traps on DDD axial downfolds may be associated are considered in some scientists works (L.N.Botvinkina, V.S. Yablokov, 1963; A.P. Feofilova, M.L. Levenstein, 1963; I.V.Vysochansky, 1986., M.I. Machujak, 1989, O.V. Bartaschuk, 1994; etc.). According to these surveys, when the DDD axial part in late Visean time started to fold down the sea covered the central part of the Dnipro Graben where the marine conditions with alteration of regressive and transgress phases of sedimentation were formed [4]. Within its limits, especially at peripheral parts of structures, in Visean paleobasin there were formed the accumulative bodies of coastal-maritime genesis:

longitudinal shore banks, banks of internals seas and bars. (V.F. Shulga, 1981; V.I. Yakymovych, 1985; J.G. Lazarchuk, 1994; O.V. Bartaschuk, 1996). During the periods of marine transgressions and related temporary periods of growth cessation of anticlinical structures the more deep-sea open marine clay sediments covered the accumulative sand bodies on downfolds resulting in the situation when the prospective reservoirs of accumulative bodies were covered up by thick clay caprocks. Thus, a number of clinoform bodies which created conditions for formation of non-folded Upper Visean traps [5].

Geological characteristics of survey area

The reinterpretation of geo-physical materials of previous years in West Solohivske deposit (O.M. Tyapkina, L.O. Bartaschuk, 2011) contributed to specify the structural tectonic model of the reflection horizon area from base of deposits of Lower Visean stage $Vв^{3\text{-}п}$ (C_1v_1) to base of deposits of Bashkirian Stage $Vб_2^{3\text{-}п}$ (C_2b) including, delineate the salt body and restore the conditions of sedimentation under the results of paleotectonic survey.

Concerning tectonic characteristics, the West Solohivske deposit is located in the Central Part of the Dnipro Graben (fig. 1) featured by the considerable depth of burial of crystalline basement (9–11 km), high power of sediment cover and manifestation of salt tectonics.

The deposits of lower vise– XIV microfaunal horizon ($Vв^{3\text{-}п}$) the West Solohivske anticlinal structure is the fold of organogenic structure in the deposits of the XV microfaunal horizon which was formed on the bench of the western part during Tournaisian period and was burned in the lower Visean Deposits of XIV Microfaunal Horizon. It is proved by transgress covering the organogenic deposits of XIV microfaunal horizon, reduction of thickness of folding and increase of thickness in the central part of the area due to salt outflow in Bakeyrian boss and formation of compensative sinking basin.

Behind the Upper Visean Deposits (XI, XII, XIIa microfaunal horizon) the West Solohivske structure is not manifested as closed, it is covered by Anteupper Visean surface of misalignment and it corresponds to a spacious north-western plunge of the Great Solohivske fold. The West Solohivske structure is separated from Solohivske fold by the system of transverse dumped deposits along all the horizons of carbon in the area of Bakeyrian boss. The western flank dips along the structure axe in Upper Visean section are gradually reduced: from 10– 12° – near Bakeyrian boss, upto 4–5° – in central part of structure.

Thus, there are two basic phases of formation of West Solohivske structure – Turne-Lower Visean and Upper Visean Serpukhiv. At the ancient stage of development in conditions of local compensative basin there were formed the deep marine dark terrigenous carbon deposits with high content of organic substance. At the second phase on the basin place there is continuous periclinal of Solokhivske anticlinal structure. During this period there was, primarily, coastal marine sedimentation characterizing by terrigenous complex of deposits – alternation of aleurolite-siltstone and clayed bands.

In wavefield of Upper Visean deposits (XII, XI) on peripheral parts of West Solokhivske structure there are fixed clinoform objects. They may be associated with transgress imbedded sand bands of producing horizon from B-20 through B-14. These geological features are favorable for formation of non-folded UV traps on structure slopes.

Traps definition methods

The main object of studies was **producing horizon B -17** of XI microfaunal horizon of Upper Visean substage. Lithographically the horizon B-17 is represented by quartz sandstone of 5 - 24 m depth. The deepest are wells 107, 111, 62 (see Fig. 2 and 3). It was tested in well 107 ($К_п$ – 7–9%, $К_нг$-85-93, $Н_{еф}$-16,6), where there was received the gas influx at the rate of 101,2 thousand m^3/day; it located on southern wing of structural high. In well 64 located in apical part of structure, there was not formation fluid influx from this horizon. In many other wells the horizon B-17 was BGP picked, generally as sealed with porosity below the limit value for visean rocks – 7%, only in well 69 it has porosity 7,1–7,4%, but it is characterized as water inundated. In other wells the horizon B-17 was not BGP picked and was not tested.

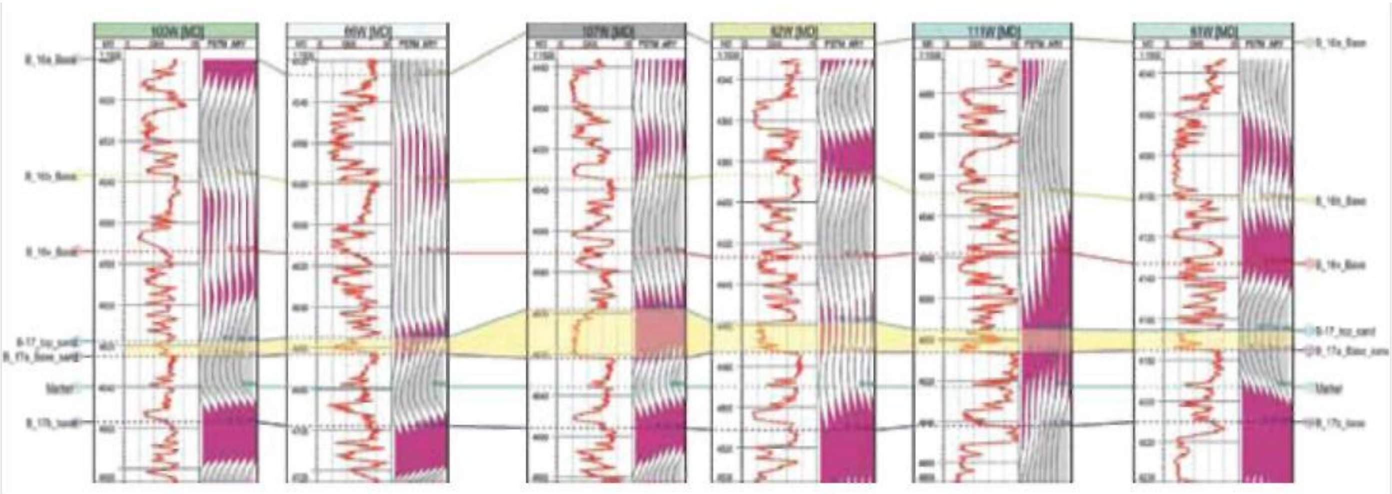

Fig. 3. Paleotectonic reconstruction of Upper Visean Deposits along line of well 100–66–107–62–111–61

There was conducted the detailed correlation of producing horizons where a particular attention was paid to producing horizon B-17 [6]. It was found a complex structure of these lithologic bands: it consists of several aleurolite-siltstone layers, having rather non-sustained character of development in section and area. As a result of detailed correlation there was established the stratigraphic belonging of productive object found in well 107 to the upper layer, namely the sand layer B-17A (Fig. 2 and 3).

Then, in the area of each well we observed the wave field for its stratigraphic correlation. Within the stratigraphic horizons there was executed the detailed BGP association, namely gamma ray log curve GK, to the wave pattern of productive sandstone and B-17 (see Fig. 2 and 3) in the time dimension using vertical seismic profiling (VSP). For each well there was mapped and analyzed the GC curves with wave pattern (see Fig. 2 and 3) and identified axle-phase, which is associated with stratum B-17A in the well 107. The sizes of the detected seismic object ranged from 10 to 25 ms, which is within one phase.

The seismic phase belonging to stratum B-17A in well 107 has excellent features compared with other parts of the section in other wells within the range of interlayer B-17A and is defined as positive with high amplitudes (see Fig. 2 and 3). On "Inline 80" it is clearly showed how seismic phase extends as bright spot from south to north in the vicinity of the folded "Xline 335", where polarity changes and amplitude decreases (Fig. 4). "Xline 261" presents the bright positive phase extending from west to east to "Inline 117" where polarity changes and dynamic reflective characteristics decrease (Fig. 5).

Based on the correlation there was built time and depth maps productive stratum B-17A of West Solohivske area. Also there was drawn a map of the thickness of layers B-17A in all wells of the field. Based on the time card within the time window of length of 15ms up and down from time-correlated surface layer of B-17A built wave field attributes - RMS (Root Mean Square) of mean square amplitude of the wave field. For clarity all these constructions are combined into a single map (see Fig. 6 and 7). These attributes of the wave field have enabled to define the accumulative body, which is clearly distinguished by high values of RMS amplitude. The map shows the accumulative body popular in South Western Part of West Solokhivske Periclinal. Behind the sandstone of B-17A it is seen that its most part are concentrated in South Western Part of Structure with tendency of increase of depth from 8 m in North East and up to 23 m – on South West in the direction of Ordaniv depression. It proves the high dynamics and intensive accumulation of terrigenous material in this part of West Solokhivske structure.

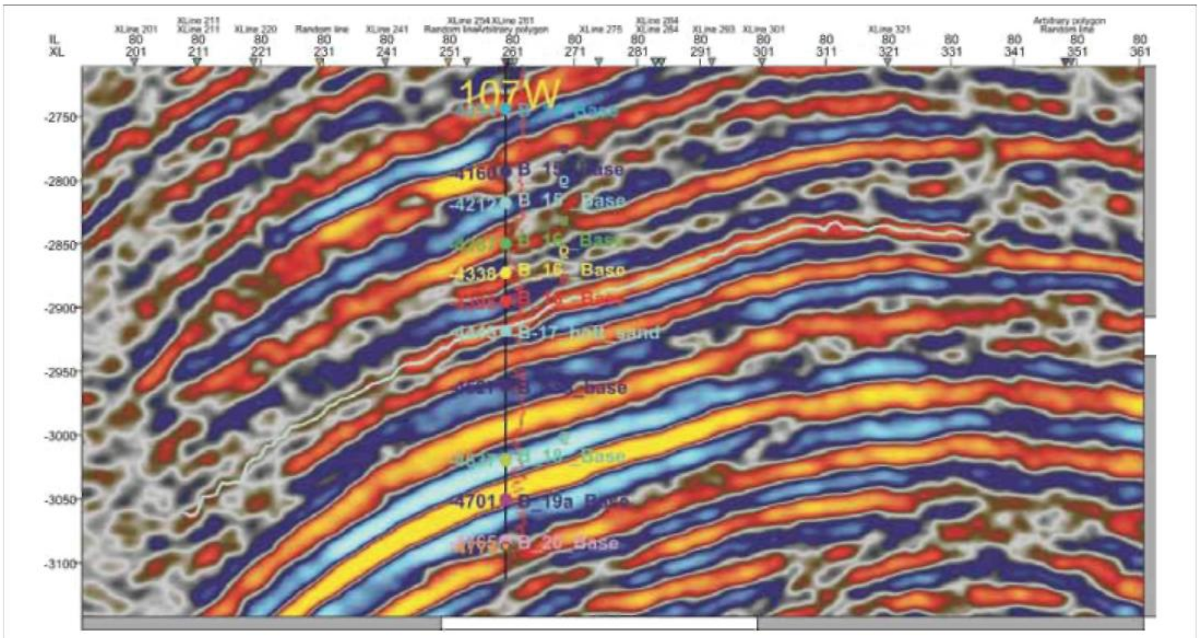

Fig. 4 Section of PreStack of time migrated cube “Inline 80” through well 107

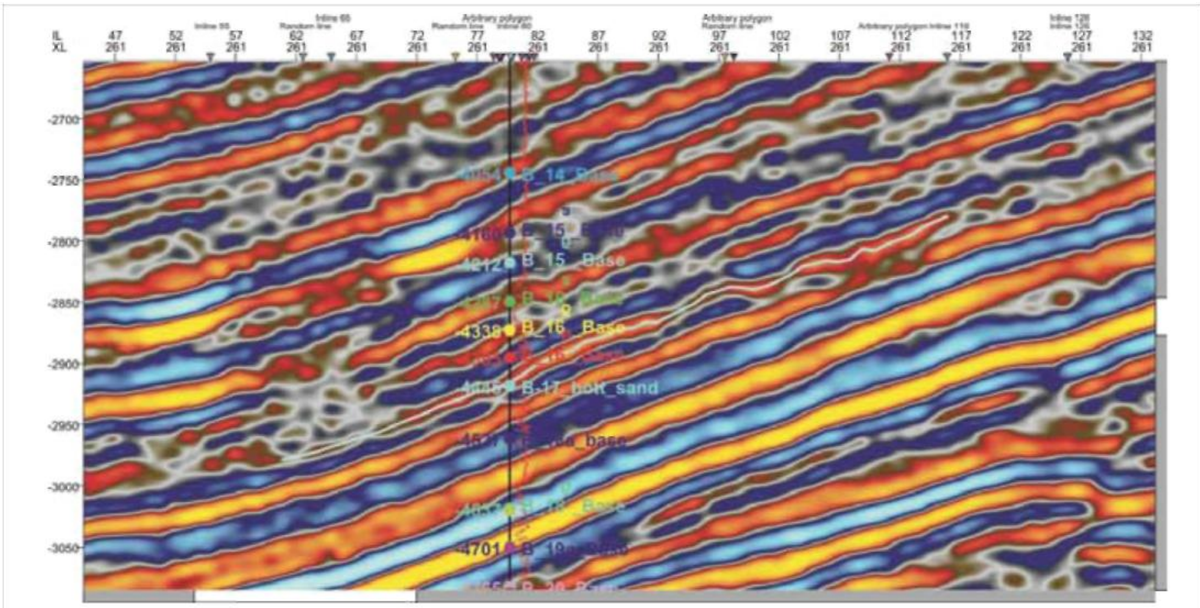

Fig. 5. Section of PreStack of time migrated cube “Xline 261” through well 107

According to data of laboratory studies of drill sample in well 107 in the sampling interval 4565–4573 m (*l* – 3,2 m), which stratigraphically belongs to horizon B-16 в-г, the rock is: 2,5 m – dark grey mudstone carbonaceous, in clearly defined layers - calcareous, interbedded with 5 cm microgranular limestone with fine organic detritus, slaty rock, splitted, medium and low strength, split by subhorizontal planes, easily turns into gravel; 0,7 m – light gray siltstone with interbedded carbonaceous subhorizontal planes, at the bottom of layer with a layer of light-gray fine-grained durable thick limestone of 0.15 m; rock is strongly cemented, splitted in subhorizontal planes by platy parting.

In the sampling interval 4676-4678 m (*l* - 0,7 m), which is stratigraphically belongs to horizon B-18, the rock is represented as follows: mudstone is dark gray to black, fine micaceous, split by subhorizontal planes. In the middle part, the sandstone layer (0.2 m) is light gray, fine-grained, strongly cemented, fine micaceous; rock with existing bedding, split by sub-horizontal planes, 0.6 m - sandstone is light gray, fine-grained, strongly cemented with millimeter layers and different amplitude suturo-stylolite seams, filled with char-micaceous and micaceous substance; subhorizontal bedding and under ∟25–30°; 6,4 m – mudstone is dark gray to black, thin-micaceous with rare prints and rare plant detritus millimeter sandstone layers described above.

Drill sample selected from water saturated parts of horizon B-17 in wells 62, 66 and from sealing parts in wells 61, 65, 102. From the saturated parts the drill samples are gray and dark gray quartz sandstone, fine-grained, fractured, dense, sometimes clay with thicknesses of individual layers and layers of 0,2-7,3 m. The sandstone is alternated with black claystone of 1,2–4,2 m and thick micaceous dack gray silt stone of 0,8 m. The effective porosity of sandstone 1,8–9,4% (in average 5,5%), openness 0–9,76×10^{-15} m^2 (in average 2,95×$10^{-15}$$m^2$). From the sealed parts in drill sample there are claystone which are dark grey to black, micaceous, sealed, with horizontal lenticular bedding of 0,4–4,5 m, with particular layers of sandstone which are grey, fine-grained, dense. In wells 61, 102 the drill sample was not studies because of reservoir absence, and in well 65 one sample of sandstone has effective porosity of 1,4 % and openness 0.

The data of analysis of drill sample proves that in Upper Visean period, especially during formation of horizons B-18, B-17 and B-16, there were primarily coastal marine conditions of sedimentation with rhythmic alteration of coastal marine and open marine facies as coastal banks, banks of inland seas, coastal spits walls, beaches and behind-bank lagoons.

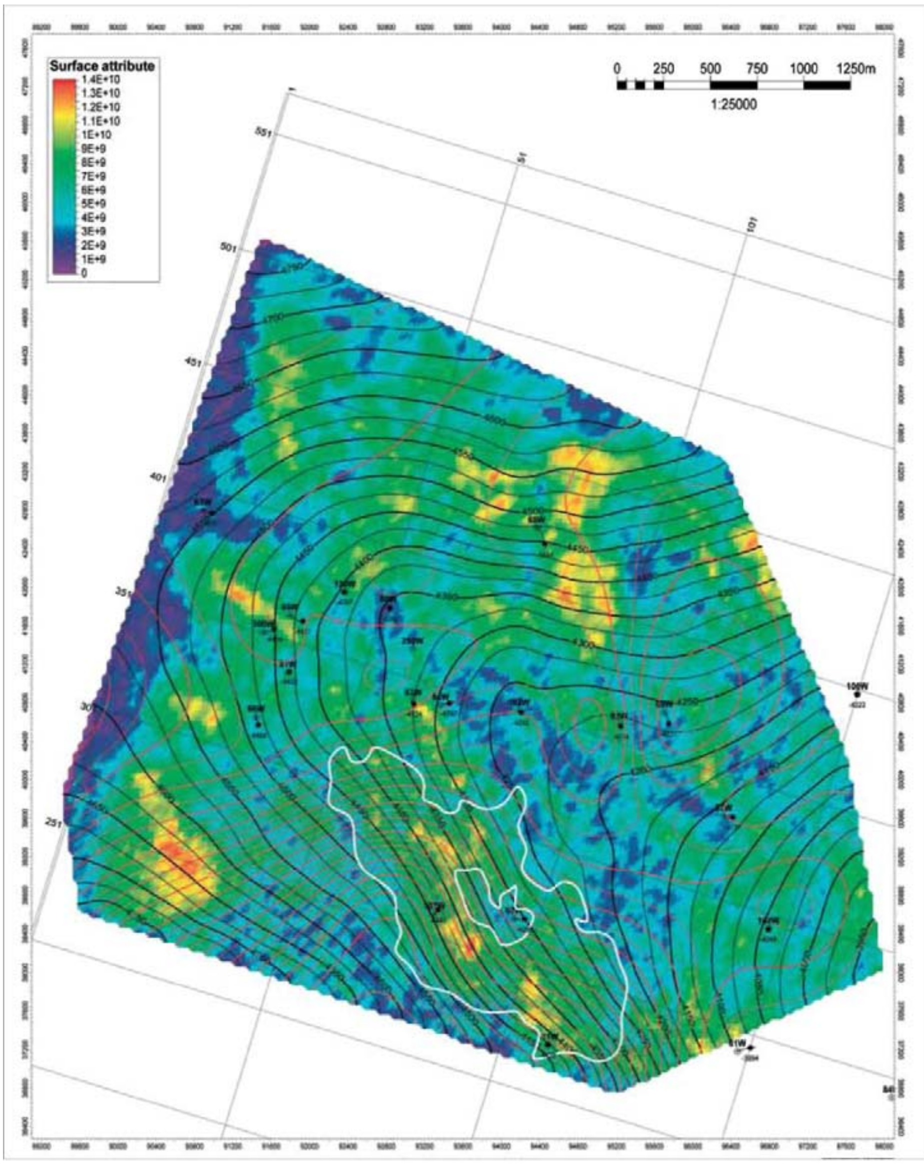

Fig. 6. Structural map, thickness and root-mean-square amplitude of wave field RMS (Root Mean Square) of sublayer B-17a

According to results of analysis of characteristics of GK curve and analysis of morphology of sand body [7] there was established the facial nature of sandstone producing layer B-17a. Model of GK curve is formed by sloping roofing line complicated by serration and horizontal direct line of plantar line. The anomaly width is 23m. The largest deviation curve belongs to the bottom part of anomalies. This is due to the fact that the energy levels of the aquatic environment varied from very high in the beginning to low at the end of the formation of sand body, so the amount of clay material to the top of the section increases. Sediments of transgress along coastal bank in the further development of regression are overlapped by behind bank lagoon sediments. At the section (see fig. 2 and 3) there are observed the alterations of transgress and regressive stages of coastal marine sedimentation with rhythmic alteration of facies of banks and behind banks lagoons, this fact is proved by carbonaceous residues and residues of fine organic detritus (based on analysis of drill). According to morphological features the sandstone body of transgress bank has convex lenticular shape in section, in plane the body has a complex elongated from northwest to southeast irregular shape (see Fig. 2 and 3): 4 km long and 1.3 km wide.

So, there was identified the genesis of producing layer B-17a on the southern periphery of the West Solohivske structure. The sand body is facially transgress coastal bank associated with ancient inland sea that existed in Upper Visean time and was separated in the northeast by extended small water marine fine-grained silt and clay sediments of lagoon facies, and to the south it was separated by clayed marine sediments of Yaroshinsky depression.

Banks of this type are often found on shoals associated with folded uplifts of anticlinal parts, expressed in seabed relief. Examples of these banks are modern islands and shoals, developed in the northern part of the Caspian Sea. The most common of these is island Kulaly that is the lunar bank, and island Chechen, composed of two sickle banks that separated the inner lagoon [7].

So, on the basis of West Solokhivske structure shows that sand bank bodies may be also widely developed and distributed on periclinal of developed structures along Yaroshinsky and Ordanivsky depressions, as well as other depressions DDD.

For the first time due to use of new complex method of forecast and finding the non-folded UV traps on the slope of Yaroshinsky depression there was defined and identified the bank body. The results of the surveys in Upper Visean deposits it is forecasted a new deep zone of oil and gas accumulation on slopes of Yaroshinsky and Ordanivsky depressions. The next phase of works should be the estimation of prospects of oil and gas content of Upper Visean Deposits, as well as improvement and increase of effectiveness of method of forecast of non-folded objects. To identify the forecasted area of oil and gas content it is recommended to set a new 3D seismic survey in the peripheral areas of proven deposits with further study of the deep slopes of axial depressions of Dnipro graben.

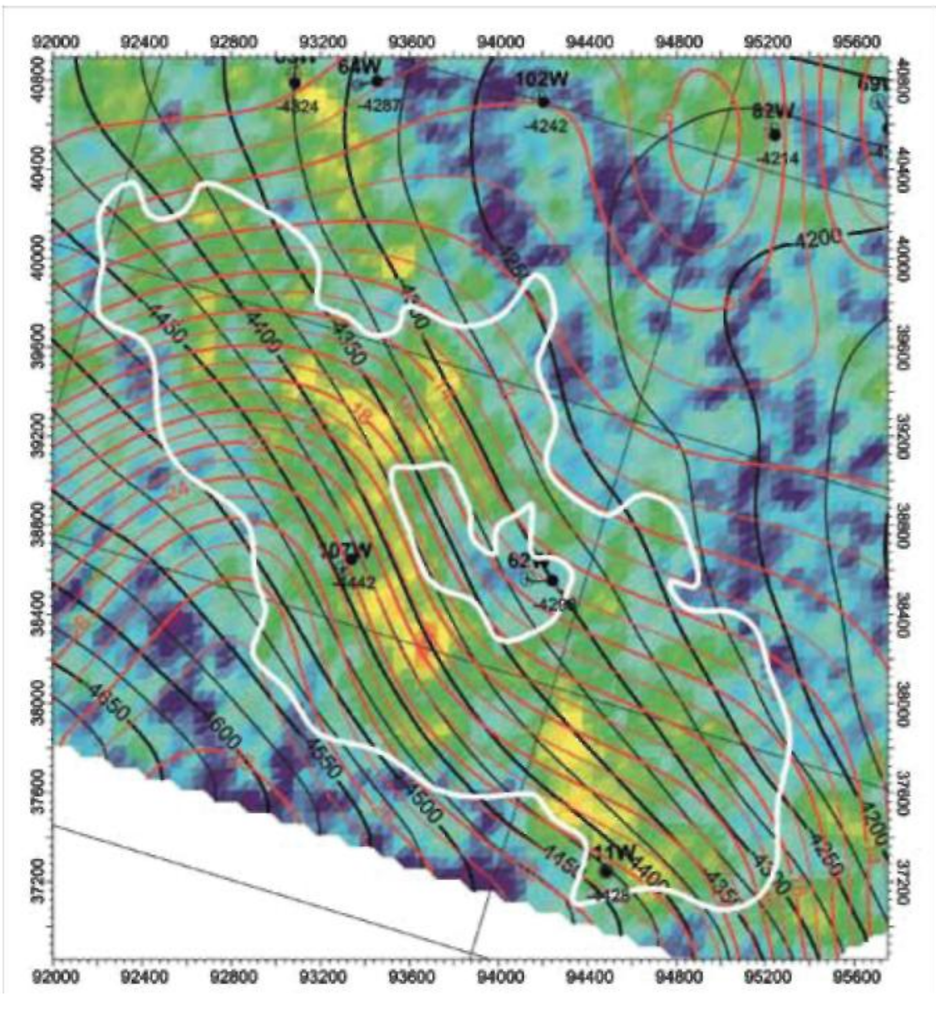

Fig. 7. Structural map, thicknesses and root-mean-square amplitude of wave field RMS (Root Mean Square) of sublayer B-17a

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M. Marukhnyak celebrates his 80th Anniversary

Marukhnyak was born on October 27, 1933, in Khodovantsi village, Tomashiv Region, Lyublin province in Poland in rural family.

In 1945 the Ukrainians who lived on Chelm Land році were evacuated, in fact, deported to the Soviet Ukraine from where the Marukhnyaks moved to Lviv (Shyrets city) oblast from Odesa oblast because of 1946-1947 famine. Here he finished secondary school and entered Lviv Polytechnic Institute, geological faculty.

First labor steps were made at Tuymasyn oil deposit in Bashkiria, then since 1960 he started his scientific activities in the Central scientific research laboratory of Production Association 'Ukrnafta'. In 1969 he defended the thesis, then he was invited to the Ukrainian State Scientific Research and Design Institute of Oil Industry in Kyiv.

Fifteen years of twenty years of activities in this institute (1970-1990) Mykola Yosypovysh was Deputy Director in Science in Geology and Drilling.

His scientific works are dedicated to justification of ways of development and increase of resource hydrocarbon base of oil industry of Carpathian, Dnipro-Donets, Azov-Black Sea, Baltic regions, defining the prospective directions of surveys, as well as coordination of *geological works in boundary regions of states of Council for Mutual Economic Assistance: Poland, Czech Republic, Hungary, Germany, USSR.*

During this period due to Marukhnyak there were developed long-term complex projects related to industrial development of hydrocarbons resources of oil and gas regions of Ukraine, Byelorussia, Kaliningrad Oblast, Lithuania and Latvia.

During seven years (1983–1989) he chaired a group of specialists of institute 'UkrDPROnafta' engaged in design of development of Cuban deposits Varadero and Boca de Haruko. Due to these woks the volumes of oil production in Cuba doubled during 5 years and achieved 1,000,000 tons per year.

In 1990, Marukhnyak was sent to Algeria where he chaired a group of soviet specialists who provided scientific technical assistance to Algerian national company 'Sonatrak' during development of hydrocarbons deposits, including giant oil Hasi-Messa-Ud and gas Hasi-Rmel deposits.

After return he worked at some responsible posts in the State Committee of Oil, Gas and Oil processing industry (1993–1998) and National Joint Stock Company 'Naftogas Ukraine' (1998–2002).

Today, Marukhnyak cooperates with Private Joint Stock Company 'Scientific Research and Design Bureau of Drilling Instrument' in solving the new technologies of development of oil and gas deposits by drilling of horizontal wells, as well as renewal of obsolete wells by side tracks.

During 15 years he was a member and an expert of the Central Committee on development of oil, gas and gas condensate deposits at the Ministry of Oil and Energy of Ukraine, he is the pioneer of some oil deposits of Pri-Carpathian and Dnipro-Donets cavity, he has over 130 published works, including monographs, brochures, scientific articles, author's certificates for inventions, geological and overview maps.

Marukhnyak is awarded with several soviet medals, distinctions and certificates. He is honorable specialist of industry of Ukraine, current member of Ukrainian Oil and Gas Academy of Sciences.